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WORMIAN BONES

CHARLES A. PARKER, M. D.
INSTRUCTOR IN SURGERY AND IN ANATOMY, RUSH MEDICAL COLLEGE,
IN AFFILIATION WITH THE UNIVERSITY OF CHICAGO

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WORMIAN BONES.

CHARLES A. PARKER.

DEFINITION.—Wormian bones may be defined as those accidental or intercalated bones found in the cranium having no regular relation to its normal ossific centres. They are of frequent occurrence in man, and generally occupy the sutures. In other animals they occur with much greater rarity.

SYNONYMS.—According to discoverer, ossicula Andernaci, ossa Goethiano; shape, ossa triquetra, ossa triangularis, ossa quadratum; location, suturaux, fontanellaires, insules, intercalaria, raphogeminantia, apicis; function, complementaria, ossa accessorii.

Schaltknochen and *Nahtknochen* are the terms in common use by the German writers, while the French writers have occasionally called them *clefs de voute*, or "keys of the vault."

One occupying the upper part of the occipital bone, the subject of considerable controversy among the anthropologists of the latter part of of the last century, is frequently alluded to as the os epactal, or os Inca. The latter name originated with the description of Tschudy, who, with Rivero, considered it a special racial characteristic of the ancient Peruvians—a contention, however, that was soon completely refuted by the larger observations of Jacquart, showing its more comprehensive generic value, and its occurrence in others than the Incas, and its very frequent absence in the race of which it was supposed to be characteristic.

HISTORY.

Occurring so frequently, and often of considerable size, they were no doubt noticed by many observers long before we had specific accounts of them. The first special description we have of them is by Olaus Worm, a Danish anatomist, 1588-1654, who described them at some length in a letter to Thomas Bartholin.

In turn Bartholin named them Ossa Wormiana, their present name. As this letter is of historical importance in establishing the author's claim to priority of description it is introduced into evidence here. The

few prefatory and closing remarks are of course not relevant here, but the complete text is given to avoid mistakes that have occurred in partial transcriptions.

Thomæ Bartholini epistolarum medicinalium, a doctis vel ad doctos scriptarum, centuria I. Hagæ Comitum, apud Petrum Gosse, bibliopolam, MDCCXL. 9 l., 416 pp. sm. 8. pp. 122-124.

EPISTOLA XXIX.

De ossiculis in sutura lambdoidea.

Thomæ Bartholino. Patavium.

Librum tuum de Luce Viventium videndi maximo teneor desiderio. Omnibus innatum lumen, unde ortum trahat, cur se in tam paucis prodat, scire gestit animus. Cocui historiam eleganter tradidit Moufettus in Theatro Insectorum lib. I. cap. 15. quem si consulueris, invenies quæ ad rem faciant: etiam de liquore ex iis præparato, noctu lucente. Cum Lugduni Batavorum adhuc hæreres & Anatomiæ Parentis editionem meditareris, de ossiculis lambdoideis me tibi scripsisse memini; sed quia, quæ, tum exarabam, excidisse videntur, jam repeto, modo usus alicujus esse possunt. Anno 1628. cum frequenti auditorum coronæ ossa sceleti humani demonstrarem atque exponerem; in ipsa sutura lambdoidea ossicula sex inveni, quæ utrumque tabulatum cranii perforabant, a nemine, quod sciam, ante animadversa. Diversissima enim sunt ab iis, in quæ os ipsum quandoque dispescitur, quod sutura lambdoidea circumscribitur, Triquetra quibusdam dictis. Tria in dextro, totidem in sinistro ejus extant ductu, magnitudine, figura & situ discrepantia. Infimum ad processum mamillarem conspicitur, medium paulo superius, vix dimidii digiti intervallo, tertium aliquanto longius a secundo distat. Figura sunt varia, triquetra, oblonga, ovalia. In sinistro ductu majora omnia apparent, quam in dextro. Maximum unguem pollicis non excedit. In concava cranii superficie distincte magis quam in convexa apparent, quocirca ablata calvaria melius observantur. Ut omnia sint clariora, iconem addo. A. portio est suturæ sagittalis. B. sutura lambdoidea. C. sectio serra facta. D. primum os sinistri ductus. E. secundum. F. tertium. G. primum dextri ductus. H. secundum. I. tertium. K. magnum cranii foramen, per quod medulla in spinam descendit. LL. Processus mammillares. Dissimulare interim hic nequeo, in diversis craniis, tam numero, quam magnitudine & figura, item situ, variare hæc ossicula. Dum hæc scribo, mihi ad manum quinque sunt crania; quorum duo suturam sagittalem per os frontis in nasum usque protendunt. Horum alterum, quatuor saltim istorum ossiculorum ostentat, atque ex iis unum in ipsa junctura sagittalis cum lambdoidea, quo in loco Triquetrum dictum, conspici solet: in altero vero duo saltim extant, eaque in dextro ductu tantum. Verum hæc crania integra erant; si calvariam auferre licuisset, forsan plura ostendisset interior superficies. Sed cum Naturam in ossibus majoribus, suturis ipsis, & aliis humani corporis partibus, varie ludere videamus, quid mirum si in hisce antiquum obtineat? In monumentis ac sepulchris majorum nostrorum licet res variæ reperiantur, ut lib. 1, cap. 7. Monumentorum nostrorum docuimus, lucernarum tamen perpetuarum nulla prorsus vestigia. Inter veterum inventa deperdita eas, ni fallor, refert Pancirollus, qui de iis ex professo agere videtur. Vale & bono publico feliter vive. Hafniæ 6, April, 1643.

T. T.

Olaus Worm D.

Of the earlier mention of these bones, Sappey refers to Hippocrates, but does not cite the instance, and a very careful search by the writer through all of the accessible editions of the works of that celebrated teacher fails to establish the claim of his priority. It is true he deals with bones and sutures, and even mentions in his fifth book of The Epidemics the case of Autonomus of Omilos, wherein he mistook a fracture near the bregma for a suture—not a suture for a fracture—with a fatal result because of delay of proper treatment. He explains his error in diagnosis as being due to the proximity of the fracture to the known sutures of that region, and in another place warns against the possibility of such mistakes being made in the neighborhood of sutures, but in no way can this be construed as an instance of an adventitious suture or an intercalated bone.

Rambaud and Renault, in their work on the "Origin and Development of Bones," mention Gonther d'Andernach, or as his biographer, E. Turner calls him, Jean Guinter d'Andernach, a German anatomist, 1487-1574, as having "discovered the os Wormiens, and Olaus Wormius gave their name."

Testut says Tourtefois claims that both Andernach and Vesale,* the celebrated Belgian anatomist, of 1514-1564, gave good descriptions of them, particularly in relation to their medical importance in cerebral affections, epilepsy, etc. Hence, the designation ossicula Andernaci as one of the synonyms mentioned by Hyrtl.

This latter author also says Paracelsus, 1460-1541, mentioned the one in the posterior fontanelle, which was called the ossiculum Antiepilepticum, on account of its supposed relation to epilepsy.

These three teachers were contemporary in the first half of the 16th century.

Yet again, Peckham, in the "Reference Handbook of the Medical Sciences," says Fischer credits an account preceding Worm's to one Goethes, in an article "De ossa epactala seu Goethiana," Moscow, 1811.

Still, it is evident that Worm's careful observations entitle him to the same distinction of practical priority that Columbus' voyage does that worthy mariner to the discovery of America, though neither, in point of fact, was actually first in his respective claim.

*Zeller mentions Vesalius as having found the squama occipitalis divided in two parts by the continuation of the sagittal suture from the lambda to the foramen magnum. The age was not given.

CLASSIFICATION.

Pozzi, in the *Dictionnaire Encyclopedique des Sciences Medicales*, divides the Wormian bones into two main groups, the false and the true, the former including those resulting from anomalous development of normal centres, as double parietals, double squamosals and interparietal bones, the os supplementaires of Manouvrier; the latter, the os intercalaires, the variety usually observed, comprising those having no such relation to the regular ossific centres, and usually situated along the margins of the bones in the sutures and fontanelles, suggesting their further division into os suturaux and os fontanellaires. To these Manouvrier adds a third variety, the os endocraniens, or insules, of Hyrtl. This division of the true Wormian bones into three classes, suturaux, fontanellaires and insules, or endocraniens, is followed by Porier et Charpey, Testut, Debierre and others.

Os endocraniens are usually small isolated fragments occurring exclusively in the inner table, and are designated by position as endofrontal and endoparietal, etc.

They are also called insular or peninsular according as they are completely enclosed in a bone or are contiguous to a suture. Manouvrier found endofrontal bones 15 times in the crania of 58 Parisians, and Hyrtl describes them in the parietal bone near the squamous margin. They have also been mentioned by Zermak, Henle and others.

Pozzi divides the os fontanellaires into the following obvious classes named in the order of frequency of their occurrence, the normal fontanelles preceding the abnormal, or infrequent ones, described by Hamy.

Normal. Os Wormien fontanellaire asterique,
Os Wormien fontanellaire pterique,
Os Wormien fontanellaire lambdatique,
Os Wormien fontanellaire bregmatique,
Os Wormien fontanellaire orbitaire, at the junction of the frontal, os planum, and lesser wing of the sphenoid.

Abnormal. Os Wormien obelique—at the obelion.
Os Wormien glabellaire—at the glabella.

To this last class Hrdlicka adds a group occupying the sites of the somewhat numerous primary fissures, occasionally remaining as supernumerary fontanelles in the margins of the developing parietal bones.

GENERAL FEATURES.

In structure Wormian bones resemble the other bones of the cranium and involve both the external and internal layers, but not infrequently they are limited to the outer layer only, much more rarely, as the os insules, to the inner.

They articulate with the surrounding bones by sutures, the dentations of which are more complex on the outer than on the inner surface of the skull.

In shape they are round, oval, oblong, triangular, quadrilateral and polygonal, and they vary in size from less than a millimeter in diameter to the one measuring 5 by 9 cm. in the skull presented by the author at the close of this article, the largest true Wormian bone whose measurements were obtainable, although the false Wormian, or interparietal bone, may even considerably exceed this.

Quain says, "They may exceed an inch in diameter": John and Charles Bell, that "they are sometimes full size of a crown"; Hyrtl, that they "vary in size from a flaxseed to a dollar"; Zeller, "from the size of a lentil to two inches or more"; Merkel, that they "vary in size even to the upper half of the occipital"; and Gruber reported one in the anterior fontanelle measuring 5 cm. by 6.5 cm.

FREQUENCY AND SITE.

The number of Wormian bones varies in different classes of skulls, and in different parts of the same skull, according to apparently well established laws. In this connection a synoptic study of the unique and comprehensive tables of Chambellan is of the greatest interest.

Victor Chambellan, to whose inaugural thesis reference has already frequently been made, who studied Wormian bones both from an anthropological and an anatomical standpoint, gives, in his extensive tables arranged from the examination of widely diversified groups of human and simian skulls, the size, location and number of Wormian bones in the several groups of the series, and, by clever comparisons and contrasts, establishes quite definite laws in regard to the relative frequency of their occurrence.

The following groups were comprised in his observations:

Auvergnats	Males	56	Females	47
Parisians	"	124	"	56
Neo-Caledonians	"	46	"	6
Negroes	"	89	"	11
Incas	"	44	"	6
TOTAL				485

Foetuses	10
Infants 12 months or less	14
Infants 2 years	1
Microcephales	5
Hemi-microcephales	15
Hydrocephales, adults	13
Hydrocephales, foetuses, infants of several months, one 5 years	8
Apes, anthropoid	52
Apes, inferior	73

For the purpose of determining the sites of predilection and relative numbers and sizes in different regions, the data from the 485 normal adult human skulls, male and female, are here condensed from Chambellan's separate catagories into one general table arranged in decreasing order of their frequence. No attempt is made to separate the male from the female skulls, nor those of different races.

The size is designated by the nomenclature of Broca, which is as follows:

No. 1 comprises all those bones which measure from 1-2 mm. in their smallest diameters.

No. 2 comprises all those bones which measure from 3-5 mm. in their smallest diameters.

No. 3 comprises all those bones which measure from 6-10 mm. in their smallest diameters.

No. 4 comprises all those bones which measure from 10-20 mm. in their smallest diameters.

No. 5 comprises all those bones which measure over 20 mm. in their smallest diameters.

For example, if the sagittal suture of a skull contain four Wormian bones measuring 1.5 mm. in their smallest diameters, and two 3.5 mm. in their smallest diameters, they would be designated, Sagittal suture, 4 (1), 2 (2). To these Chambellan has added the designation, +1 (plus 1), for those bones less than a millimeter in their smallest diameters, but which he thinks should be recorded in an exhaustive study.

Furthermore, as the number of skulls examined varied in the different races and sexes, the results were originally given for each group in terms of 100 skulls for purposes of ready comparison, a method which for the same practical reason will be made use of here.

Table showing the size, number and location of Wormian bones in 100 normal adult human skulls, estimated from a total of 485 skulls of both sexes and several races, arranged in decreasing order of their numerical frequence. (Modified from Chambellan).

Lambdoid suture, right	19.49 (+1),	19.77 (1),	33.58 (2),	27.88 (3),	9.17 (4),	0.42 (5).	Total	110.31	Total both sides—215.81
Lambdoid suture, left	17.16 (+1),	16.98 (1),	30.66 (2),	33.96 (3),	6.41 (4),	0.33 (5).	Total	105.50	
Coronal suture, right	50.33 (+1),	24.02 (1),	0.34 (2),	0.59 (3),			Total	75.28	Total both sides—126.22
Coronal suture, left	47.24 (+1),	1.85 (1),	1.15 (2),	0.70 (3),			Total	50.94	
Mastoparietal, right	4.52 (+1),	12.30 (1),	3.28 (2).	1.95 (3),	0.34 (4),		Total	22.39	Total both sides— 45.18
Mastoparietal, left	4.35 (+1),	10.22 (1).	6.18 (2),	2.04 (3),			Total	22.79	
Asterion, right	0.08 (+1),	1.74 (1),	6.48 (2),	10.80 (3),	1.59 (4).		Total	20.69	Total both sides— 35.48
Asterion, left	0.08 (+1),	1.35 (1),	5.18 (2),	5.67 (3),	2.51 (4),		Total	14.79	
Pterion, right		2.63 (1),	2.68 (2),	8.84 (3),	2.29 (4),		Total	16.44	Total both sides— 28.00
Pterion, left		0.19 (1),	6.54 (2),	3.06 (3),	1.77 (4),		Total	11.56	
Squamoparietal suture, right	2.24 (+1),	4.09 (1).	4.86 (2),	2.22 (3),	0.48 (4).		Total	13.89	Total both sides— 27.19
Squamoparietal suture, left	2.64 (+1),	5.05 (1),	4.59 (2),	0.86 (3),	0.16 (4),		Total	13.30	
Sagittal suture	7.82 (+1),	7.85 (1).	2.18 (2).	4.04 (3),	0.85 (4),	0.29 (5),	Total	23.03	
Masto-occipital suture, right	1.24 (+1),	1.86 (1),	2.56 (2),	3.04 (3).			Total	8.70	Total both sides— 19.83
Masto-occipital suture, left	0.16 (+1),	3.50 (1),	1.70 (2),	5.44 (3),	0.22 (4),	0.11 (5),	Total	11.13	
Orbit, right	0.40 (+1),	6.42 (1),	2.32 (2),	0.59 (3),			Total	9.73	Total both sides— 11.29
Orbit, left	0.18 (+1),	1.20 (1),	0.18 (2),				Total	1.56	
Metopic suture	3.52 (+1),						Total	3.52	
Sphenofrontal suture, right	0.18 (+1),	0.18 (1),		0.18 (3),			Total	0.54	Total both sides— 1.08
Sphenofrontal suture, left	0.18 (+1),			0.36 (3),			Total	0.54	
Bregma		0.18 (1),		0.27 (3),			Total	0.45	
Obelion	0.08 (+1),			0.08 (3),			Total	0.16	
TOTAL	161.89 (+1),	121.38 (1),	114.46 (2),	112.57 (3),	25.79 (4),	1.15 (5).		537.24	

The greatest frequency of Wormian bones in the lambdoid suture is attested by all observers: containing as it does, with the addition of the asterion and masto-occipital sutures, as its continuations, 271.12 bones, or one-half of the whole number present in all the skulls. Hyrtl observed 300 in this suture in the skull of a cretin, the largest number found recorded in a single skull. Liston reported 100 in a hydrocephalic skull, but no reference is given of the sutures involved. That the coronal suture should stand second as a site of predilection for these bones in normal skulls is a source of some surprise, as this region is not usually considered as specially favoring their existence (Humphrey), though Dorsey has particularly remarked their increased frequency in this suture in artificially deformed skulls. Sandifort observed them in this suture.

Hrdlicka distinguishes a number of the Wormian bones occurring in the sutures surrounding the parietal as fontanelle in origin, and elsewhere their frequency is given, but no other statistics based upon such a distinction are available.

In an illustrated article entitled "Wormian Bones in the Artificially Deformed Kuaikuitl Crania," appearing in the *American Anthropologist* for June, 1897. Dorsey comments upon the frequent occurrence of Wormian bones in the coronal sutures of the deformed skulls of this race.

They were found 10 times in 60 skulls, occurring rather more frequently in females than in males, and oftener on the left side than on the right. In one case there were 5 bones on the right side, and 2 on the left.

With this article in mind an analysis was made of the cases in the museum of the Royal College of Surgeons, England, given in the catalogue of 1879, Part I.

Total number of crania mentioned, 1010.

Total number mentioned as having Wormian bones, 79, including cases of epactal and epipteric bones.

Number containing Wormian bones in coronal suture, 15.

Further analysis of these 15 showed the following:

They occurred 9 times in males, once in a female, and 5 times in crania of unknown sex, some being children. They were present on the right side in 14 cases, on the left in 10, and on both sides in 8. Their numbers were not given frequently enough for study.

In 20 skulls of flat head Indians, 7 contained Wormian bones, and in 5 they occurred in the coronal sutures, the frequency of occurrence in this suture being 71 per cent. of the skulls containing these ossicles. Taking out these 5 cases from the special total of 15, and the 7 cases from the general total of 79, there remain 10 examples of coronal occurrence in 72 cases of Wormian bones, a frequency of 14 per cent. A com-

parison of the 71 per cent. of frequency in the flat heads with the 14 per cent. in other skulls shows the predilection of this site in the former to be five times as great as in the latter.

In explanation of this striking peculiarity Dorsey says, "These skulls are deformed by bandages and flattened in front, projecting behind, often showing a groove just behind the coronal suture from the bandages * * * * They are probably due to elongation of the skull, and consequent faulty union of the parietals with the frontal."

Next in frequency to the coronal are the mastoparietal sutures, and the asterions, the points of divergence of the former from the lambdoid.

Following these in decreasing succession are the pterion, the squamoparietal, sagittal and masto-occipital sutures, the orbits, the metopic and sphenofrontal sutures, the bregma and obelion.

Ninety-three per cent. of the whole number, or 501.52 of these bones, are situated in the sutures bordering the parietal bones, a distribution quite proportionate to the greater relative extent of these over the remaining sutures of the membranous cranium.

Gruber observed their presence in the squamous suture on one or both sides in 5 per cent. of 4,000 skulls, and Humphrey mentions that they may here be two or three rows deep.

In the skull later presented by the writer, the whole squamae temporales and adjacent portions of the parietals consist of numerous Wormian bones, completely obliterating this suture, and rendering separate distinction of asterion and pterion ossicles impossible.

Although they are very rare in the face, and between the sphenoid and neighboring bones, according to Merkel they are frequently met along the orbital margin, and Ward has observed them in the ethmosphenoidal suture and in the lesser wing of the sphenoid.

Hyrtl records one in the internasal suture, and one in the crucial suture of the palate. Gegenbauer mentions their occasional occurrence at many points in the articulation of the bones of the wall of the nose or the maxillary region.

Mitchell and LeCount, at a necropsy on a case of acromegaly, observed two Wormian bones in the roof of the right orbit and four in the roof of the left. Their numerous occurrence in the orbits of the skull, previously mentioned by the writer will later be noted. (Figs. 21, 22.)

Metopic Suture. Simon reports numerous Wormian bones throughout the length of this suture in the skull of an adult male. Chambellan reports two cases of Wormian bones in this suture, and Gruber an os interfrontal at the site of the bregma, but in front of the coronal suture.

Robert Harrison, in the "Dublin Dissector," says that "the os frontis may develop in three parts, the third being ovoid and situated in the median line separating the two lateral halves, a specimen of which is in the museum."

Intraparietal Suture. A very unusual site is the abnormal intraparietal suture in divided parietals. Hrdlicka, in his recent extensive work on the parietal bone, records seven cases, collected from literature, of these bones situated in this suture in man. Five were on the left side, and two on the right. (Fig. 1.)

Here, also, should be mentioned the isolated observation of Gruber, who found in the petro-spheno-basilar sutures of 100 skulls, 119 extra bones varying in length from 2 to 26 mm., and in width from 1 to 9 mm., and from the thinness of paper to 5 mm. thick. They were spongy or compact in structure.

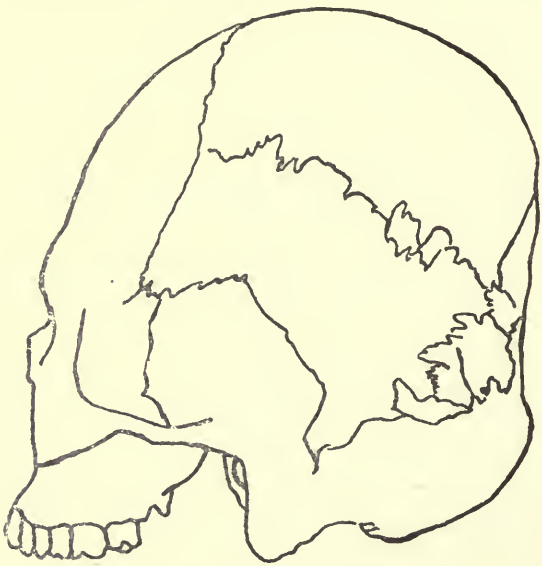

FIG. 1.—Wormian bones in anomalous parietal suture. (After Hrdlicka, "Parietal Bone in Man and Other Mammals," p. 258, drawn from photograph of Putnam's first case of parietal division.)

The frequency given them here would place them fourth in rank, or next to the mastoparietal suture.

Their occurrence in the fontanelles has been noted in the following order of their frequency: asterion, pterion, lambda, bregma, and orbital fontanelle.

Os Wormien Asterique. Chambellan found 36 cases in 110 skulls of Parisians. When single they usually range in diameter from 4 to 8 mm., but they may be found measuring but 1 or 2 mm.

They are not rarely symmetrical in their presence on the two sides, though this is not at all constant.

Os Wormien Pterique. The same author observed this bone but 14 times in 110 Parisians.

These bones vary in size, number and distribution, similar to those at the asterion, and may extend variable distances along the upper border of the squama temporalis even as far as the posterior border. (Fig. 2.)

Os Wormien Lamdatique. This bone is situated, as its name implies, in the posterior fontanelle, and is mentioned by Worm as frequently assuming a triangular shape. Hyrtl says it was mentioned by Paracelsus, and called os antiepilepticum on account of its supposed relation to epilepsy. In 100 Bavarian skulls Ranke found this bone present four times.

FIG. 2.—Wormian bones in the squamous suture.

Os Wormien Bregmatique. This bone was first described by Bertin, and is situated in the anterior fontanelle. In the skulls of 198 Parisians Chambellan encountered it but twice. In one case it was oval, and in the other quadrangular in form. They were single and of nearly equal dimensions, measuring 8 to 9 mm. in width by 2 cm. in length, their long axes corresponding in direction with the sagittal suture. (Fig. 3.)

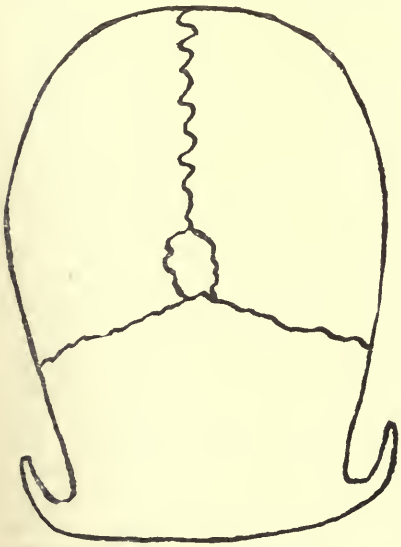

FIG. 3.—Os Wormien bregmatique, occupying the anterior fontanelle. (After Chambellan.)

Gruber, in a series of contributions to *Virchow's Archives*, reports 70 cases found in the examination of 11,928 skulls—an average of 1 in 170. One of these measured 5 cm. by 6 cm., the largest he had ever seen. In two instances there were three bones, one being the skull of a hydrocephalic boy; and in one case they were double.

Quoting Humphrey, "Bertin Cruveilhier and Cuvier, each describe the os bregmatique, and Tiedemann, in the *Ztschr, f Phys.* III, gives plates of two in this situation; also Sandifort in his "Mus. Anat." Tab. VIII. There are several examples in the museum of Bonn. Blandin, "Anat." I describes them in each of the fontanelles." Tiedemann mentions Stehelin Doveren, Tarin and Sandifort also having observed bregmatic bones.

Os Wormien Orbitaire. This is situated at the junction of the frontal, os planum of the ethmoid and lesser wing of the sphenoid. Chambellan had not seen a single instance in the nearly five hundred skulls he had observed. They are present in both orbits of the skull presented by the writer, along with numerous others in the neighboring sutures. (Figs. 21 and 22.)

Abnormal Fontanelles. In the abnormal fontanelles, Chambellan records two cases of *os Wormien obelique* occurring at the site of the obelion in the skulls of 198 Parisians. They occurred singly, and were somewhat smaller than the ones previously described at the bregma, their long diameters extending transversely instead of sagittally. (Fig. 4.)

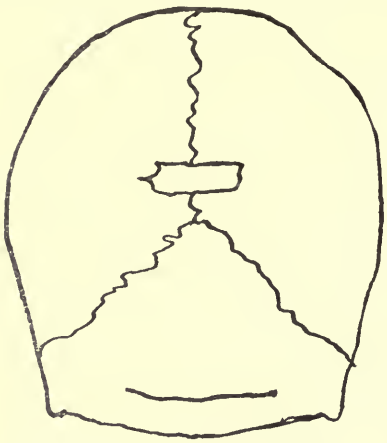

FIG. 4.—Os Wormien obelique, at the site of the abnormal fontanelle obelique. (After Chambellan.)

Hamy applies to the same bone the name os sagittal, but os obelique is the preferable designation, as it refers to a definite place.

In the descriptive catalogue of the Warren Museum "a Wormian bone the size of the finger nail in the middle of the sagittal suture, an unusual situation, in the skull of a child four or five years old" may possibly be an example of this bone.

M. Pozzi observed one instance of *os Wormien glabellaire* in the nasofrontal fontanelle in 485 skulls; but Chambellan never encountered it in the nearly 500 he examined.

In this class are included the fontanelle bones mentioned by Hrdlicka, referred to in a previous chapter, which heretofore have been considered sutural rather than fontanelle in location. Few observers have attempted this distinction, and occasionally the multiplicity of bones makes the differentiation quite impossible, but the attempt is justified by the author in the following assertion: "The recognition of the fontanel bones adds considerably to our proper understanding of the subject of intercalated bones and diminishes very much the numbers of the purely accidental of these ossicles."

In the examination of 45 complete skulls he found 33 of these bones in 17, the majority being along the posterior border of the parietals and usually classed as lambdoidal. In 105 calvaria, upon which observations were necessarily limited to the remaining portions, 9 examples were seen.

DEVELOPMENT.

Kolliker describes the development of the parietal bone as follows:

"In the region of the parietal bone is first seen a number of small isolated ossific centres which become more numerous and blend with one another. * * * It grows partly through the enlargement of the existing osseous framework, and partly by isolated centres, while at the same time the interspaces are filling up with an osseous material, till at the end a thin compact bone is formed." (Fig. 5.) What is here said with reference to the parietal bone may be applied with equal truth to the other membrane bones of the cranium. The further development, according to Gegenbauer, "is accomplished by small bony crests radiating toward the periphery. Between the parts already formed, new ones appear, or else distinct bony pieces may be formed outside the growing borders of the bones, and later fuse with the principal piece. However, this fusion of isolated pieces does not always occur, and it sometimes happens that these pieces remain independent, forming little bony fragments in the dentations of the sutures. These are found regularly in the occipital sutures. When they are found at an advanced stage of development these little bony pieces may grow without joining the neighboring bones. We then find distinct bones in the sutures, relatively large, and articulating by dentate sutures with the adjoining bones. These are the so called intercalary or Wormian bones."

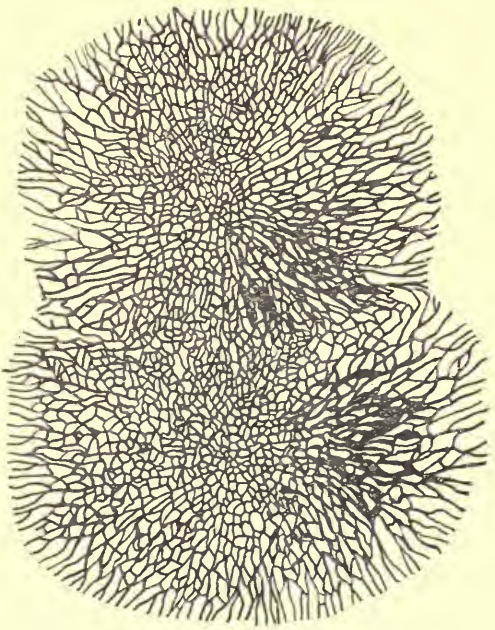

FIG. 5.—Embryonal parietal bones, showing two centres of ossification. (After Ranke.)

The origin of Wormian bones by supernumerary centres or by division of primary centres is axiomatic, since they must either arise by separate

centres and remain distinct, or develop as a part of the regular centres and in some manner later be severed from their origin.*

A later development of occasional small Wormian bones is mentioned by Chambellan, Sappey, Porier et Charpey and others, as due to the gradual compression and final obliteration of the pedicle of a denticule by its adjacent denticules. This is but another method of origin by separation from a primary centre.

Their mode of growth is similar to that of the larger bones, taking place by radiation from the centre to the periphery.

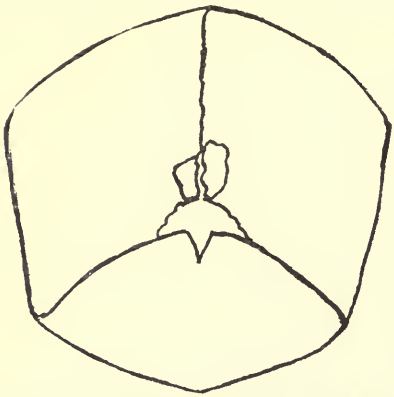

FIG. 6.—Skull of an infant, showing two Wormian bones, occupying the site of the parietal foramina—fontanelle obelique. (From the Gyn. and Obstet. Mus., Rush Medical College.)

Time of Appearance. Beclard says they do not develop till five or six months after birth, a statement with which Humphrey apparently agrees; but it is a matter of common observation that they are not infrequent in infants at birth. Chambellan, in the skulls of ten fetuses observed six in the lambdoid suture, all of small size. In the crania of fourteen infants under twelve months, and one child of two years, he observed ten instances, occurring in the lambdoid suture, pterion, asterion and obelion. In the Museum of Obstetrics and Gynecology, Rush Medical College, are a number of fetal skulls showing minute osselets in the lambdoid and other sutures. The skull of an infant in the first postnatal months shows two bones occupying the site of the parietal foramina. One, triangular, measures 7 by 8 mm. in its longest diameters, the other, oblong, 4 by 7 mm. (Fig. 6.)

In the same collection, No. 77, is the skull of a somewhat older infant, showing the large Wormian bones occupying the right half of the lambdoid suture, materially changing its course, and developed at the expense of both the parietal and adjacent occipital bones. The larger bone measures 4 by 5 cm. and the smaller 2 by 3 cm. They are not the result of fracture. The posterior fontanelle is inlaid with a mosaic of numerous thin flat bones from 1 to 2 mm. wide, and 5 to 10 mm. long, arranged in quite definite vertical lines. (Fig. 7.)

A few similar shaped ones are present in the anterior and lateral fontanelles.

*See Cruveilhier, Rauber, Humphrey, Hyrtl, Macalister, Merkel, Cunningham, Wistar, Chambellan, Rambaud et Renault, Porier et Charpey, Sappey.

This striated or radiating arrangement is mentioned by Humphrey as having been observed by him in hydrocephalic skulls where they appeared like extensions of the radiations of the normal bones, from which, however, they were quite separate.*

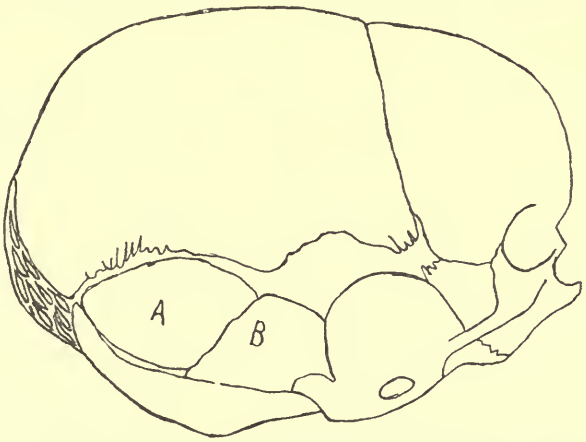

FIG. 7.—Skull of a newborn child showing large Wormian bones, A and B, in the right lambdoid region. Many smaller bones are also present in the posterior fontanelle. (From the Gyn. and Obstet. Museum of Rush Medical College, No. 77.)

This form of growth results from the linear arrangement of separate centres in a suture rendering lateral development unnecessary and impossible, permitting only extension in a vertical direction, producing a palisade formation across the gap to the opposite bone.

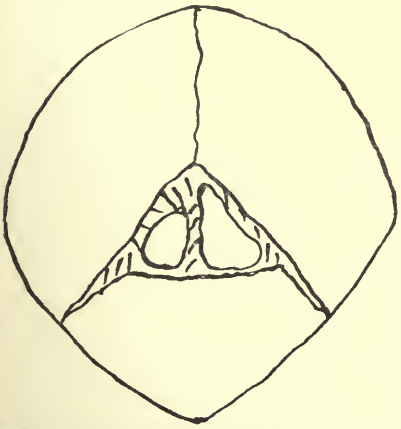

Fig. 8.—Skull of an infant whose stillbirth is ascribed to the influence of the Wormian bones in the posterior fontanelle. (Grace Peckham. "Ref. Handbook Med. Sci.," 1894, Art. "Wormian Bones.")

Peckham, in the "Reference Handbook of the Medical Sciences," gives a cut showing two Wormian bones of considerable size in the posterior fontanelle of a newborn infant. (Fig. 8.)

In some cases they doubtless arise synchronous with the larger normal centres, as for instance, the large Wormian bone occupying such a considerable portion of the frontal region of the skull later presented in this article, having a greater area than the largest piece in the parietal region; but, just as under normal conditions some centres of ossification appear later than others—when the necessity arises for them—so it is probably true of these bones that their

*Examples of this are referred to by Humphrey in the Museum of the College of Surgeons No. 3842, and in Sandifort's "Mus. Anat." Tab. VII. Fig. 2.

period of origin extends over considerable intervals of time, even a number of years, in some instances.

It is evident, that with the exception of the few small ones mentioned as occasionally formed by inclusion of a denticule, and obliteration of its pedicle, as may occur almost any time during adult life, the most of these bones appear during the earlier years of cranial development, while the fontanelles are open and the bones separable at the sutures, as the only time when they may be of service or can obtain room. Chambellan says they are most frequent in adults in those skulls with open sutures, becoming fewer as the sutures are obliterated. Cruveilhier says their sutures are the first of all cranial sutures to be effaced. This is more particularly true for those of smaller dimensions than for the larger ones which seldom disappear entirely, though they may be partially united to the neighboring bones. Their diminution in number with the obliteration of the sutures is the natural consequence of the disappearance of the conditions—sutures—which originally distinguished them from the adjacent bones, causing them eventually to become integral parts of the latter.

FUNCTION.

With reference to their function Cruveilhier says:

"They are looked upon as supplementary points of ossification, and not as playing an important role in the mechanism of the solidity of the cranium, as would be supposed from the name, 'Keys of the vault,' or '*Clefts de voute*,' given them by some anatomists." Ward expresses similar views, though he quotes Bichat as saying they are designed to strengthen the cranium. According to Humphrey; "They are evidently stop-gaps developed in the membranous covering of the brain when the extension of the regular osseous nuclei is likely for some reason to be insufficient to cover the cranial cavity." Wistar says practically the same, and Manouvrier, "They are due to an insufficiency of the normal centres."

MORPHOLOGY.

As to their morphological value they are not reversional types as a rule, the more numerous bones of the skulls of other animals having their representatives in the separate ossific centres from which the larger bones of the human cranium are regularly formed, and not in the occasional Wormian bones. (Humphrey, Manouvrier.) According to Macalister, "They are a testimony of the low morphological value of centres of ossification in membrane bones." Merkel says, "For the most part they are the product of a development with too little energy."

Yet, at times division of the parietals or irregular development of the occipital and other bones may present features of considerable morphological interest, often making it difficult or impossible to distinguish between those bones developed separately from normal centres, and those arising from true supernumerary ossific areas. The peculiar manner of development of the squama occipitalis affords opportunity for a great variety of examples of irregular development with consequent confusion of morphological relations. The lower part of the squama occipitalis, including the inion, is developed in cartilage, while the remaining upper portion is developed in membrane. As formerly taught by Broca, 1875, and most other anatomists, the entire squamous portion is developed by four centres of ossification placed in two superimposed symmetrical pairs, the upper in membrane and the lower in cartilage. The adjacent portions of each pair fuse, and then the upper part unites with the lower, beginning at the inion, leaving at first vertical and horizontal incisures at the margins.

The horizontal incisures are frequently present at birth. Failure of union of the upper portion with the lower results in the formation of the socalled interparietal bone, the analogue of a separate bone of that name constant in many of the mammalia. This bone is developed from normal centres, and is therefore not a true Wormian bone.

Since then Merkel and Kolliker, 1879, and Hagen and Anoutchine, 1879 and 1880, have described eight centres of ossification instead of four for the squama occipitalis; the first two authors arranging them four on a side, one above the other, the last two arranging them three on a side, one above the other, with the fourth placed lateral to the third, or uppermost one, which makes the summit of the bone. In 1881 Hannover of Copenhagen, reduced the number to two, one for the membranous portion and one for the cartilaginous portion, thus reverting to the views of Sappey in 1867. Debierre in 1895 gave six centres of ossification for the squama occipitalis. (Porier et Charpey.)

Wiedersheim in the same year, in his "Structure of Man," gives the same number of centres, and arranged in a similar order as follows: supraoccipital, from the cartilaginous portion, interparietal and preinterparietal, the latter according to the author, being constant as a separate bone only in the horse.

According to Debierre its occurrence in man constitutes the os epactal.

The accompanying diagrams from Wiedersheim's work, show very clearly this morphology. (Fig. 9.)

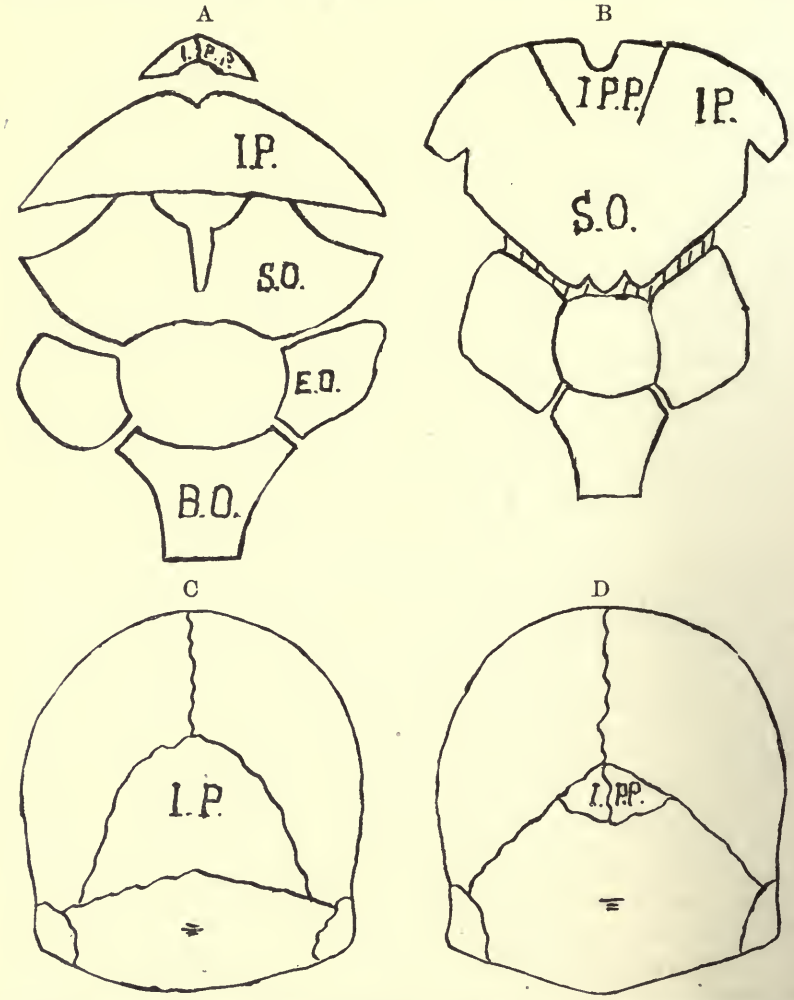

FIG. 9.—Development of the occipital bone. (After Dr. R. Wiedershelm, "The Structure of Man," 1895, p. 56.) A Development of the squama occipitalis by six centres. S O, supraoccipital; I P, interparietal; I P P, pre-interparietal; B O, basioccipital; E O, exoccipital. B Later stage of development. C Interparietal bone formed from the upper four centres. D Pre-interparietal bones formed from the upper pair of nuclei. These remain normally separate only in the horse. (Wiedersheim designates these latter as interparietals, though the view expressed here appears to be the proper one, judging from the plan of development.)

Figures 10, 11 and 12 are instances of irregular development of this region. (For Fig. 12 see page 24.)

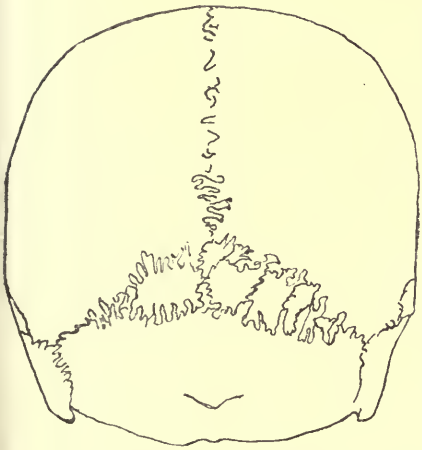

FIG. 10.—Wormian bones in the lambdoid suture. (From the Anatomical Laboratory of Rush Medical College.)

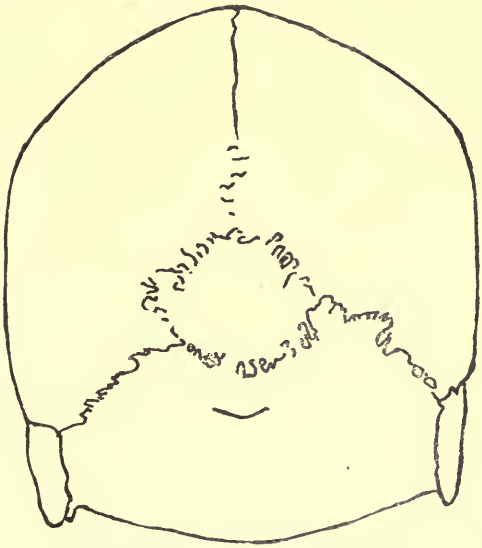

FIG. 11.—Quadrangular bone occupying the apex and adjacent portion of the squama occipitalis, apparently representing the enlarged and ununited pre-interparietal portion. (From the Anatomical Laboratory of Rush Medical College.)

With this evident confusion as to the exact number and arrangement of the centres in this region of the skull, further "testimony of the low morphological value of centres of ossification in membrane bones," the frequent impossibility of accurate distinction between true and false Wormian bones is manifestly apparent. Still, certain special terms are applied to more or less regular formations commonly observed here. They are the os interparietal, os epactal and os Inca.

INTERPARIETAL BONE.

By many authors these terms are synonymous and cover a considerable range of variation from all of the membranous portion of the squama occipitalis to a small os lambdatique. The following description by Broca probably best represents this special formation, including as it does all of the membranous portion of the occipital bone, the line of the adventitious suture, the interparietal, corresponding exactly with the lower posterior limit of the development of Wormian bones in the skull later described in this article.

"L'interpariétal se distingue par la position de sa suture qui aboutit de chaque coté à la partie inferieure de la suture lamdoïde et qui, sur la ligne mediane passe a peine a un centimetre et demi au dessus de l'Inion."

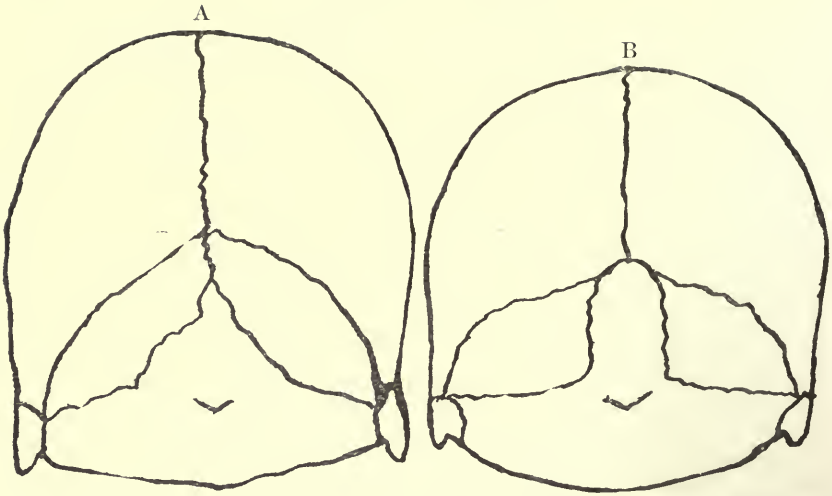

FIG. 12.—Peculiar development of the occipital bone observed in two skulls in the Osteological Collection at the University of Chicago. In A the two symmetrical lateral areas apparently represent a divided interparietal separated by the sagittal suture above, and by a tongue of bone extending from below. In B the separation is more complete, the tongue of bone entirely separating the two portions. In both cases the "interparietal" suture is present the greater part of the distance from the mastoid process to the inion.

OS INCA.

Rivero and Tschudi in their "Peruvian Antiquities" described a bone later designated under this name. As much confusion exists as to its morphological position the following quotation from these authors is here introduced:

"In conclusion it may be proper to notice an osteologic anomaly, very interesting, which is observed in the crania of all the three races (Chincas, Aymares, Huancas) and it is this; that those children of tender years, in the first months after birth, present an interparietal bone (os interparietal) perfectly distinct; a bone which, as its name indicates, will be found placed between the two parietals, and having a form more or less triangular, whose sharpest angle is above, and is bounded by the posterior edges of the parietal bones, while its base attaches itself to the occipital bone by a suture which runs from the angle of union of the temporal with the occipital bone, a little above the semi-circular line, to the similar angle on the opposite side. It follows that this interparietal bone occupies precisely that part of the occiput which in the other crania is occupied by the upper portion of the occipital, and which is connected with the parietals by the lambdoid suture. At four or five months this bone is regularly united to the occipital. It is a circumstance worthy of attention of learned anthropologists, that there is thus found in one section of the human race a perpetual anomalous phenomenon, which is

wanting in all others, but which is characteristic of the ruminant and carnivorous animals."

The exposition of the fallacy of this premature conclusion, by Jacquart, has already been mentioned. Gosse came to similar conclusions regarding their morphological significance, although he believed they more frequently remained separated in the Peruvians.

This accurate description, together with the accompanying figure (Fig. 13.), from the same source, leave absolutely no room for doubt as to its morphology, that it represented the generally recognized interparietal bone of today developed from the entire membranous portion of the squama occipitalis.

FIG. 13.—Skull of a youth of the Chincas, 10 to 12 years old, in which the "occipital" suture may be seen open throughout its whole length. (From "Peruvian Antiquities," p. 38.)

OS EPACTAL.

Broca makes no distinction between the os epactal and the os Inca, which he describes as follows:

"L'os des Incas est un os Wormien, triangulaire, qui est vraiment surnuméraire, qui est symétrique de grande dimension et qui occupe le lambda."

Chambellan also considers the two terms synonymous, and asserts that it may be single or double, or even divided in three parts. According to these authors it is not an interparietal, which is a false Wormian bone. These conclusions must be based on entirely erroneous conceptions of the os Inca as just described, and detract from the force of their opinions with regard to the os epactal.

Topinard, Jacquart, Rambaud et Renault, Milne Edwards, Testut, Porier et Charpey, Cunningham and many other writers use the word interparietal and epactal as synonymous terms designating varying proportions of the squama occipitalis, making no endeavor to apply them separately to different formations; thus probably best avoiding the confusion naturally arising from too much specialization in a region normally of such doubtful morphology.

The writer believes that the term interparietal, in its true sense, should be applied only to the bone developing from the whole membranous portion of the squama occipitalis, the lower boundary of which has already been described by Broca, as a suture converging from either side at the lower part of the lambdoid to pass in the median line scarcely one and one-half centimetres above the inion.

As it is evident that the terms os Inca and os epactal, as they are generally used, are rather suggestive of authority than of morphology, further consideration of them need not be given.

ANTHROPOLOGICAL SIGNIFICANCE.

Especially interesting from the anthropological standpoint is the significant relation between the number of Wormian bones and the cubage of the skulls selected for study. This is shown in the following tables from Chambellan, the number of bones being on a basis of 100 skulls for each group.

No. of Skulls Observed.	Name of Group.	Total Number of Wormian Bones.
Males		
56	Auvergnats	626
124	Parisians	587
46	Neo-Caledonians	519
89	Negroes	501
44	Incas	481
Females		
17	Auvergnats	600
56	Parisians	551
6	Neo-Caledonians	455
11	Negroes	427
6	Incas	493

Cubage of Male Skulls.

No. of Skulls Observed.	Name of Group.	Capacity.
44	Auvergnats	1,535 cc.
40	Parisians	1,511 cc.
38	Neo-Caledonians	1,471 cc.
38	Negroes	1,410 cc.
37	Incas	1,324 cc.

The Auvergnats have the most Wormian bones, 626 to 100 skulls, the Parisians, Neo-Caledonians and Negroes following in order of decrease to the Incas with but 481.

Comparing these numbers with the cubage of the corresponding skulls a similar regular decrease in capacity is shown from the Auvergnats to the Incas, thus establishing the general conclusion that the number of Wormian bones is greatest in the skulls of the largest capacity, and correspondingly diminishes as the cubage decreases. See the following table:

Auvergnats	626	Wormian bones.	Capacity,	1,535 cc.
Parisians	587	"	"	1,511 cc.
Neo-Caledonians	519	"	"	1,471 cc.
Negroes	501	"	"	1,410 cc.
Incas	481	"	"	1,324 cc.

The cubage of the female skulls was neglected, yet a diminished total in each of the groups except the last, probably accounted for by the small number of skulls (six) observed, shows here also the same definite correspondence between the numbers and the well known smaller capacity of these skulls.

Analagous and equally interesting results corroborative of this relation are obtained by examination of the data relating to the other groups of skulls examined by this writer.

Hydrocephales, adults.	13	1092	Wormian bones.	Capacity .....3,727 cc.
Hemi-microcephales ...	15	366	" "	" less than 1,100 cc.
Apes, anthropoid	52	96	" "	" in gorilla 531 cc.
Microcephales.....	5	40	" "	" ..... 433 cc.
Apes, non-anthropoid..	73	17	" "	" much less than microcephales.

The commonly observed increase of these bones in hydrocephalic skulls is here very apparent.

Comparing these with the skulls of the Auvergnats, the largest normal skulls studied, the relation of number to capacity is very strikingly shown.

Auvergnats.....600 Wormian bones..... .....Capacity, 1,535 cc.
Hydrocephales.....1,092 " " ..... " 3,727 cc.

Equally noticeable is the diminished number in the crania of small cubage as the anthropoid apes and microcephales.

Chambellan also studied their occurrence in brachycephalic and dolichocephalic skulls, examining fifty of the former and twenty-five of the latter, with the result of finding the equivalent of 676 Wormian bones to the hundred skulls in the former, and 362 in the latter.

A comparison of the cubage of some of these skulls gave the following results:

No. of Skulls.	Total Capacity.	Average.
Brachycephales, 12.....	.....18,311 cc.	.....1,525 cc.
Dolichocephales, 28.....	.....42,145 cc.....	.....1,505 cc.

The number of skulls is too small to furnish the most desirable proof, but from all that has been shown the evidence is very conclusive that in spite of numerous isolated exceptions, the general rule for groups holds good, that *the number of Wormian bones increases with the capacity of the skull, regardless of the cause of the enlargement.*

Finally their occurrence on the two sides of the head was separately recorded with the following results:

Parisians.....	Right side	281.....	Left side	255
Auvergnats.....	" "	307.....	" "	288
Neo-Caledonians.....	" "	299.....	" "	197
Negroes.....	" "	295.....	" "	215
Incas.....	" "	257.....	" "	230

Showing their greater frequency on the right side in all the groups examined.

SUTURAL LENGTHS.—With the object of establishing a probable direct relation between the increase in Wormian bones, and the general increase in sutural length, and between their preponderence on the right side and a greater corresponding dextral sutural length, careful measurements were made by the writer upon 50 normal skulls to obtain data upon which conclusions might be based. Measurements were made of the coronal, lambdoid, squamous, (including the sphenoparietal and mastoparietal), and sagittal sutures, as they comprised most of the sutures bearing Wormian bones. In the first three, including the two transverse sutures, the two sides were recorded separately. The cephalic index was also taken in each case, and the skulls divided into dolichocephalic, mesaticephalic and brachycephalic classes. The average total sutural length in 22 dolichocephalic skulls was 78. cm., in 16 mesaticephalic skulls 78.7 cm., and in 12 brachycephalic skulls 79.8 cm., or including the last two in one group, in 28 brachycephalic skulls 79.2 cm. Chambellan determined that the brachycephales have a greater cranial capacity than the dolichocephales—he did not distinguish a middle class —and that they also have a larger number of Wormian bones corresponding to their increase in cubage, agreeing with his previously mentioned law that as a class the larger the cranial capacity the greater the number of Wormian bones. A comparison of his results with those obtained from the foregoing sutural measurements suggests certain fundamental relations; first, as the brachycephalic skulls have a greater number of Wormian bones and also a greater sutural length, that *the greater the sutural length of a skull the greater the number of Wormian bones;* and, second, as the brachycephalic skulls have a greater cranial capacity with a greater sutural length, that *the larger the cranial capacity of a skull, the greater its sutural length.* In other words, in man at least, the number of Wormian bones and the capacity of a skull bear a direct relation to the length of its sutures.

These relations thus established by tangible data are such as we would *a priori* expect to obtain, since the Wormian bones develop in the sutures and the longer the suture the greater the opportunity for increase in their numbers, and the greater the cranial capacity the longer the sutures necessary to unite the enlarged parts. In the first principle also is to be found the explanation of their greater frequency on the right side, as the total sutural length of the right side of the 50 skulls was 1,666.2 cm., as compared with a total of 1,643.5 cm., on the left, the excess being limited to the squamous and coronal sutures. Although of secondary importance to the main subject, certain interesting observations appear in the comparison of the coronal and lambdoid sutures in the two general classes of skulls. In the 22 dolichocephales the coronal

sutural length averaged 22.7 cm., and in 28 brachycephales 23.4 cm., while the lambdoid in 22 dolichocephales averaged 19.5 cm., and in 28 brachycephales 19.3 cm., showing a very definite increase in sutural length, associated with a corresponding increased cranial capacity, in the anterior and lateral regions of the brachycephalic skulls with a stationary or slightly diminished capacity in the posterior region of the same skulls. The lateral increase is particularly emphasized by similar comparisons of the squamous sutures in the three classes of skulls, as the average length in 22 dolichocephales was 23.2 cm., in 16 mesaticephales 23.5 cm., and in 12 brachycephales 24.9 cm., a progressive increase from the first to the last. At the same time the sagittal suture is shortened from an average of 12.6 cm., in dolichocephales to an average of 12.4 in brachycephales. The direct relation of the increase in size in this region—the temporal fossa—to brachycephaly, with special reference to the causative factor of the jaws in its production, is admirably demonstrated in an exceedingly interesting scientific paper by Arthur Thomson, presented before the recent International Medical Congress, at Madrid.

CAUSES.

The larger number of Wormian bones doubtless arises from local metabolic variations entirely physiological and compensatory in character. Their innocuous occurrence in practically all normally developed skulls is opposed to an essentially pathological origin, and only when presenting particularly abnormal features should it come into consideration. Their occasional association with definite pathological processes may be secondary or incidental, and rarely a direct or specific result of the primary affection. Pathological or physiological variations can directly produce Wormian bones in but two ways; either by permanently segregating offshoots from pre-existing centres, or by causing an excess of original centres themselves. As the distinction between physiological and the milder pathological fetal nutritional variations is frequently so obscure the difficulty of positively ascribing these effects on osteogenesis to definite pathological causes is plainly apparent. A physiological excess of primary ossific nuclei, possibly sometimes hereditary or atavistic is well known to occur, and it is possible that some of the definite pathological processes, or the more subtle so called degenerative influences may also occasionally produce similar results; but there is no doubt that most of the Wormian bones properly ascribed to specific pathological processes directly affecting osteogenesis are produced by the permanent segregation of nuclei from pre-existing centres.

Rachitis, scrofula, violent pressure, heredity, syphilis, and in addition, in the writer's case, osteogenesis imperfecta, chondrodystrophia fetalis, and cretinism, have all been considered in the pathology of their

development. Lombroso and Ferrero assert their increased frequency in the crania of criminals. Of the pathological conditions in which the occurrence of Wormian bones is but incidental or secondary to the primary affection, hydrocephalus is probably the best known. Other affections gradually producing great cranial enlargement would probably lead to equally excessive development of these bones.

Their production by pressure is evidenced by their increased frequency in the coronal suture in the skulls of the flat head or similarly deformed Indians reported by Dorsey, and those referred to by the author in a previous paragraph. Whether flattened by direct pressure on the occiput and forehead, or by compressing bands around the back of the head, the compensatory lateral enlargement is especially effective in the coronal region, correspondingly increasing its predilection for Wormian bones. Their occurrence is secondary to the sutural diastasis.

The role of heredity in their production without the relative occurrence of pathological features is distinctly physiological.

Their association with stigmata of degeneration, tuberculosis, syphilis and similar dycrasiae must be considered quite incidental to the primary affection, and only possessing a possible aetiological relation when presenting distinctly unusual or abnormal local features.

Chondrodystrophia fetalis and osteogenesis imperfecta are prenatal in origin, rachitis and cretinism are essentially postnatal affections, though possibly occasionally occurring earlier under the influence of maternal dycrasiae similar to their own specific pathologies. Except in the latter extremely rare instances, the influences of these two chronological classes of affections on osteogenesis must differ considerably in their opportunities, if not in their effects; the prenatal affections alone being capable of profound fundamental disturbances of osteogenesis, the postnatal diseases being limited in the production of separate nuclei to their action on the margins of the bones only.

Osteogenesis in cretinism exhibits a similar characteristic sluggishness or inhibition in its course to that observed in the growth of other tissues in this disease, a condition apparently most unfavorable to the development of supernumerary ossific nuclei; although in the single case mentioned by Hyrtl the extraordinary number of 300 was found in the lambdoid suture of a cretin.

On the other hand, however, the notably irregular osteogenesis of rachitis would appear to specially favor the separation of such nuclei from pre-existing centres, and this disease is particularly mentioned by Gosse as one of the causes of Wormian bones. Yet its postnatal occurrence and usually short duration necessarily reduce its direct aetiological relation to narrow chronological and mensural limits.

Chondrodystrophia fetalis is a fundamental disease of chondrogenesis, secondarily affecting only bones of chondral origin so that while the base

of the skull may present gross deformities the membrane bones show no specific alterations. It thus bears no aetiological relation to Wormian bones.

Osteogenesis cranii imperfecta, or aplasia cranii, with its irregular development of isolated patches of bony tissue, appears to be the best known pathological condition to favor excessive development of these bones. A beautiful specimen of this condition is the fetal skull described by Vrolik in a later paragraph. (Fig. 23.)

Back of these fetal dystrophias commonly lie parental, usually maternal, dyscrasiae, and, in the Vrolik case syphilis apparently played an important part. In the writer's case Prof. Hektoen, in a separate article more especially concerning the general dystrophy, considers rachitis, cretinism, chondrodystrophia fetalis and osteogenesis imperfecta as possible causes of the various body changes. As neither the changes in the skull nor in the body conform to those of rachitis or cretinism, they were excluded as aetiological factors, and the preference given to osteogenesis imperfecta and chondrodystrophia fetalis. The body changes with the short and misshapen limbs correspond closely with those observed in the latter disease, and differ from those of the former in the apparent absence of multiple fractures. On the other hand, the changes in the cranium correspond to those of osteogenesis imperfecta, while the base of the skull presents none of the lesions of chondrodystrophia fetalis.

The successive occurrence of the two diseases is doubtless possible, but the restriction of the two processes to separate and distinct areas instead of each acting generally, develops an apparently unique variation from the usual types. Considering the analogy between this skull and the one described by Vrolik, its excessive number of Wormian bones can best be ascribed to the changes occurring in osteogenesis imperfecta. On account of the incomplete history it is impossible to determine any parental dyscrasiae.

The changes in the face of this skull, of a distinctly degenerative character, are in all probability due to the same general dyscrasia variously affecting the different regions of the body.

MEDICAL ASPECTS.

Their specific medical importance is exceedingly limited. By simulating normal sutures or fractures, the occurrence of adventitious sutures may occasion confusion in examination of the skull.

Nicolas Saucerotte, in his "Melanges De Chirurgie," mentions the case of a clergyman who was thrown from his horse and suffered an injury in the occipital region. The first attendant on examining the wound, pronounced it a fracture of the skull, and suggested trephining as the proper treatment. Dr. Nouvelle, a clever surgeon of the time, was called in consultation, and opposed the diagnosis of fracture. He contended that the apparent line of fracture was the adventitious suture of a Wormian bone. The skull was not trephined. Upon his recovery the grateful clergyman promised, should he die first, that the doctor whose knowledge and skill had saved his skull intact while he lived should have the opportunity of examining it after his death. Some years later he died, and the doctor found at the site of the injury a triangular shaped Wormian bone measuring one inch and ten lines in its greatest diameter, by one inch and a half in its lesser, occupying the upper angle of the occipital bone, its transverse suture having previously been mistaken for a fracture of the skull. This is the only instance I have found recorded of a Wormian bone becoming of surgical importance, although it is highly probable that such confusion has not been so rare as this single record would indicate.

In the "*New York Medical Record*" for 1888, Grace Peckham reports three cases occurring during her internship in the New York Hospital for Women and Children, in which Wormian bones in the posterior fontanelle gave rise to confusion in the examination of the presenting head, and were considered responsible for the death of all three children, as no instruments were used in the deliveries. These are the only recorded instances in which pathological influences are ascribed to these bones.

AUTHOR'S CASE OF EXTRAORDINARY DEVELOPMENT OF WORMIAN BONES.*

This interesting skull was obtained by Prof. Hektoen at an autopsy on a white man about 45 years of age. The man had been a resident of Chicago, and possessed only a fair degree of intelligence. He had always been a cripple, the most noticeable deformities being a marked dorso-lumbar kyphosis and very imperfectly developed and misshapen limbs.

The special body changes have been described by Prof. Hektoen in a separate article.†

The skull presents on lateral view an unusually high cranium overtowering a small, receding face, and protruding lower jaw. In front it has a narrow oval outline with high orbits and irregular teeth. (Figs. 14 and 15.)

Various measurements were made and compared with the average of ten normal skulls, and are given in the following table. The measurements are in centimetres unless otherwise stated.

Cranium.	Specimen Skull.	Average Skull.
Greatest length	17.2	18.3
Greatest breadth	13.2	14.6
Cephalic index	76.7	80.1
Circumference	49.5	52.6
Biauricular distance over bregma	35.	....
Basio-bregmatic height	15.	12.4
Vertical height from external auditory meatus to bregma	13.5	12.1
Capacity	1450 cc.	1450 cc.
Basion to foramen caecum	9.7	8.3
Distance from inion to vertical dropped to basion	8.	7.9
Basion to spenocribriform junction, Huxley's base line	6.6	6.4

*The skull was presented at the fifteenth annual session of the Association of American Anatomists, at the University of Chicago, Dec. 31, 1901 to Jan. 2, 1902, and a brief abstract was later published in the proceedings of the society.

†L. Hektoen. Anatomical Study of a Short Limbed Dwarf, with Special Reference to Osteogenesis Imperfecta and Chondrodystrophia Foetalis.—Amer. Jour. Med. Sci., May, 1903.

	Specimen Skull.	Average Skull.
Sphenoid.		
Occipitosphenoidal synchondrosis to spheno cribriform junction—length of sphenoid	4.4	4.3
Postsphenoid	2.	2.3
Presphenoid	2.5	2.2
Pituitary fossa, depth	1.	.9
diameter, transverse	1.5	1.3
diameter, antero-posterior	1.	1.2
Foramen magnum, length	3.7	3.7
breadth	3.4	3.1
Face.		
Basion to nasion	10.1	10.1
Basion to posterior inferior angle of nasal bone	9.	9.7
Basion to prosthion	7.5	9.6
Basion to gnathion	9.2	11.6
Basion to supraorbital notch	10.	10.2
Basion to middle of infraorbital margin	7.5	8.6
Basion to posterior nasal spine	3.7	4.
Nasion to prosthion	6.2	7.1
Nasion to gnathion	10.7	12.
Nasion to gonion	10.5	12.5
Prosthion to gnathion	4.3	....
Mandible.		
Gonion to gonion	9.	9.9
Gonion to gnathion	6.5	9.1
Palate.		
Length	3.4	4.9
Breadth, interalveolar	3.7	3.8
Nasal Cavities.		
Anterior nares, height	3.	3.1
width	2.1	2.3
Posterior nares, height	2.5	2.7
width	3.5	3.

The maximum length is 17.2 cm., the maximum breadth 13.2 cm., with a corresponding circumference of 49.5 cm.

The height from the basion, or anterior margin of the foramen magnum, to the bregma, is 15 cm. Although a comparison of these figures with those averaged from ten normal skulls shows both the breadth and length to be slightly over 1 cm. short of the average, yet the height, which is increased by over 2 cm., completely compensates for the circumferential constriction, as shown by the capacity of 1450 cc., that of the average normal male skull. The cephalic index is 76.7, hence the skull is of the mesaticephalic type.

The internal surface of the base presents little variation from the average skull in form or measurements; the foramen magnum is normal in size, shape and location, as are also neighboring parts of the occipital bone, except that the upper part of the tabular portion is composed of Wormian bones.

The thickness varies from 2 mm. laterally in the temporal region, to 9 mm. in the frontal and occipital, the average being 4 to 5 mm.

The distance from the basion to the foramen caecum is 1 cm. above the average, which, considering the shortness of the skull and normal location of the basion, appears disproportionate, but is explained by the absence of the frontal sinus and crest. The foramen is situated 1 to 2 cm. nearer the anterior surface of the skull and correspondingly farther from the basion.

It is not unusual to find the distance from the glabella to the foramen more than 2 cm., while in this skull it is less than 1 cm.

The distance from the basion to the occipitosphenoidal synchondrosis is normal, as is also the distance from the latter to the anterior superior angle of the sphenoid at the cribriform suture. The cerebral surface of the presphenoid measures 2.5 cm., while the postsphenoid measures but 2 cm., giving an index of 125, obtained by dividing 100 times the former by the latter, the average being very close to 100, or both parts equal. In a series of skulls examined the maximum was 113, and the minimum 87.

While the total length of the cerebral surface of the sphenoid is not affected, the disproportion between the two parts is unusual, and constitutes the only noteworthy variation from the ordinary measurements in this region.

Although somewhat asymmetrical in general outline, the entire cranium presents but slight variations from the normal measurements, the moderate circumferential constriction being accompanied by vertical elongation with undiminished capacity, and the disproportion between the pre- and postsphenoid making no difference in the length of the floor.

The peculiar shape of the skull with the recession of the face may be represented by superimposing an outline of a median section of the skull upon a similar outline of an average skull, so that a line from the basion to the sphenocribriform junction, the base line of Huxley, in one, exactly corresponds with a similar line in the other, their uppermost ends being at the same point. (Fig. 19.)

RECESSION OF FACE:—If the facial profiles be represented by two irregular curves drawn through the nasion, posterior inferior angle of the nasal bone, prosthion and gnathion, a comparison of them will show that they lie quite near at their upper ends at the nasion, and progressively diverge to the prosthion the point of maximum separation of 2.4 cm.,

from whence they continue nearly parallel or slightly converging to the gnathion, where the difference from the average skull is about the same as at the prosthion.

The curves are obtained by joining the arc connecting the three upper points with that connecting the three lower at their point of intersection. (Fig. 20.)

A series of measurements from the basion successively to the aforementioned parts compared with a similar series the average of ten normal skulls confirms the results obtained by direct comparison of profiles showing no recession at the nasion, agreeing with the measurements of the base of the skull, a slight foreshortening at the posterior inferior angle of the nasal, the portion most commonly present of the lower extremity of that bone, and most marked at the prosthion where the difference as above stated is over 2 cm.

Although the lower jaw protrudes beyond the upper, and relieves in some measure the appearance of recession, it also shares in the general defective development of the face, and is decidedly shortened, the gnathion, or most prominent part of the symphysis menti, being 2.4 cm. nearer the basion than normally, and its intrinsic length from gonion to gnathion 2.6 cm. below the average.

A series of horizontal profiles drawn through the various levels mentioned compared with those of a normal skull show in each plane concentric curves with increasing recession of the lateral regions of the face similar to that in the mediau line.

The vertical curves are eccentric, the horizontal concentric. There is a vertical shortening of the face of 1.3 cm.

As the face is but slightly narrowed the main fault of development is in the sagittal plane with but little, if any, in the coronal, and as the recession is symmetrical, affecting both sides of the face alike, it is evidently the result of some general cause exerting its principal influence in a sagittal direction. The recession is not due to the premature ossification of the basiosphenoid cartilage with consequent shortening of the base of the skull, as has already been shown, nor to an excessive flexion of the face on the cranium from any other possible cause, as the normal distance separates the basion and the posterior nasal spine, the meeting point of the vomer and palate bones, which from their relation to the base of the skull would be the ones most influenced by its flexion. It is therefore necessarily due to the changes in the bones of the face itself, and principally and primarily in the maxillæ, as the ones most influencing its form. The true facial profile is formed by the nasal and maxillary bones, with the former resting upon the superior maxillæ; so that changes in the latter affecting their nasal processes produce corresponding variations in the positions of the nasals, the upper ends of which remain with the cranium proper, while the lower ends follow the changes of the max-

illæ and swing on the upper as on a pivot. The increasing recession from above downward reaching its acme at the maxillæ is co-ordinate evidence of the primary responsibility of these bones for this feature of the skull.

As the evolution of the teeth is the most important factor in the growth of the jaws, and perversions in this process produce irregularities in the development of the maxillæ, a consideration of the dentition is essential to a proper appreciation of the maxillary changes.

DENTITION.

SUPERIOR MAXILLÆ.

Incisors. The upper jaw contains two large, well spaced median incisors, and one small lateral incisor on the right side, half the normal width, and separated from the median by a space equal to its own width.

Canines. The canines are well developed, the left being shifted one centimeter nearer the median line through non-development of the lateral incisor. Its ridge also participates in the shifting and borders the lateral margin of the anterior nares. The intermaxillary suture is deflected slightly to the left as it approaches the alveolar margin.

Premolars. Two well developed and partially rotated premolars are present on the left side, and one, the distal, well developed and partially rotated, on the right. Two unoccupied alveoli, one lateral and one medial, are present behind this single premolar, the former probably being for the absent second premolar, and the latter of small size, of unknown function.

Molars. The first molars only are present on either side, the second and third never having erupted.

There are six teeth on the right side, and five on the left. The absence of the left lateral incisor with mesial shifting of the canine is accompanied by marked left sided flattening, producing considerable asymmetry of the alveolar arch. Vertically they are much shortened, and the nasal processes separated from the frontal by intervening Wormian bones.

MANDIBLE.

Incisors. Two shallow alveoli mark the place of two missing central incisors that were of fair size, judging from the space left for them.

One lateral incisor is present on the right side but none on the left, corresponding with the same condition in the upper jaw.

Canines. The two canines are present, the left being 5 cm. nearer the symphysis than the right.

Premolars. The first premolars are present on either side.

The second premolars are absent on both sides.

On the left side is a narrow interval between the first premolar and the first molar with no alveolar absorption; on the right an interval of

two centimeters exists between the first premolar and the second molar with absorption of the alveolar process, which probably once contained a well developed second premolar and a first molar.

Molars. The first and second molars are present on the left side; and the second with an erupting third on the right, the first as just mentioned probably having formerly occupied the region of the absorbed alveolus.

Counting the two median incisors whose alveoli are present, there are six teeth remaining in each lateral half, the total number erupted on the left side, while on the right side there were eight, the full number.

This excess of the right side over the left of eight to six, is similar to that in the upper jaw, which is as six to five. As in the upper jaw, the absence of the left lateral incisor, and mesial shifting of the canine, determine a flattening of the curve on the same side accompanied here by an abrupt bend at the canine tooth. The muscles of the cheeks and lips evidently were important acessories, producing the reciprocal changes in the jaws for the articulation of the teeth.

The length of the right half from the symphysis to the posterior border of the ramus exceeds the left by 1 cm. As there is no backward displacement of the ramus and the normal curve is maintained, the increased length causes a slight displacement of the symphysis to the left of the median line.

A slightly increased relative deficiency over that of the lower jaw exists in the length of the upper, corresponding to the more incomplete dentition. The distance between the condyles corresponds with the normal measurements of the base of the skull.

This study of the dentition renders very apparent the role of the teeth as an important causative factor in the production of the facial deformity; and, as the permanent teeth are the ones more evidently involved, the disturbing process, doubtless prenatal in origin is seen to have extended through a considerable number of postnatal years, in this respect corresponding with the changes occurring in the growth of the chondro-skeleton as shown in the fragile and misshapen bones of the trunk and limbs.

POSTERIOR NARES. The posterior nares measures 2.5 cm. in height and 3.5 cm. in width. In the average normal skull the two measurements are practically equal.

This great disproportion between the height and width of the posterior nares gives a broadening effect, which with the incomplete dentition already noticed, stamps the face anatomically of the infantile type rendering the general deformity particularly conspicuous because of the adult cranium.

WORMIAN BONES.

By far the most interesting feature of this skull is the extraordinary development of Wormian bones, numbering 172. (Figs. 14, 15, 16, 17, 18.)

These bones are most numerous in the posterior and lateral regions of the skull, supplanting the larger portion of the parietals, the squamous portions of the temporals, and the upper half of the tabular portion of the occipital.

Several occur in the vertical and orbital plates of the frontal, particularly in the vicinity of the nasal notch. The portions of the cranium free from them are the lower half of the tabular, the condyles and basilar portions of the occipital, the mastoid and petrous portions of the temporals, the sphenoid and ethmoid bones, or those parts developed primarily from cartilage, the chondro-cranium.

They range in size from 3 mm., and even less in the posterior and lateral regions, to one measuring 5 by 9 cm. in the upper part of the frontal bone.

They are mostly irregularly circular in form, with coarse and fine dentations for articulation with similar adjacent bones. All layers of the bones are affected, the outer surface presenting the most irregular and uneven serrations, the inner showing fewer irregularities combining with the others, making a smooth, even surface next the dura.

Parietal bones. Three-fourths of each parietal bone are represented by various sizes of Wormian bones, ranging in diameter from 3 mm. to 3 cm., the remaining fourth consisting of a single quadrilateral segment measuring 4 by 8 cm., occupying the anterior superior angle, separated from its fellow by the sagittal suture, and forming with the frontal the upper part of the coronal suture. Bordering the coronal suture on either side below the larger segments are three or four of smaller size ranging from 2 cm. to 3 cm. in diameter. The temporal ridges are indistinct or absent. On the inner surface the grooves for the meningeal arteries are well marked. The average thickness is 3 to 4 mm.

Temporal bones. The squamae temporales consist almost entirely of various sized Wormian bones, their slender interlocking processes presenting an appearance resembling a delicate pattern of lace work. As previously mentioned the mastoid and petrous are not involved.

Occipital bone. The line of separation between the membranous and cartilaginous portions of the squama occipitalis is distinctly marked by a curved denticulated suture extending from one mastoid region to the other, rising in the middle 1½ cm. above the inion, corresponding exactly to the lower boundary of the interparietal bone as outlined by Broca. The part above this suture is composed entirely of Wormian bones, as is well shown in the posterior view of the skull. (Fig. 17.)

Frontal bone. The unusually high frontal bone is divided into two nearly symmetrical halves by the persistent metopic suture. The entire

upper portion of the right half exists as a separate bone, cut off from the lower part by a suture extending from the metopic laterally to the coronal. This large Wormian bone is somewhat quadrilateral in form, and measures 9 cm. in length by 5 cm. in width.

Twelve small Wormian bones are located in the suture between the orbital plates and the alæ parvæ of the sphenoid, the cribriform plate, and lateral masses of the ethmoid, the lachrymal, and the nasal processes of the superior maxillæ, forming a considerable portion of the upper and inner walls of the orbit. None, however, exists in the nasofrontal suture. The distribution by numbers in the different regions may approximately be given as follows:

Frontal bone,	12.
Parietals, each,	40.
Temporals, each,	25.
Occipital,	30.

Sutures. The sagittal suture extends uninterruptedly from the nasion to within one and a half centimeters of the inion, or throughout the total median extent of the membranous cranium, a condition normally present only in intrauterine life.

This suture is quite distinct throughout, the Wormian bones that border it for the greater part of its extent not attempting to cross it more than the usual dentations common to the normal suture. In the frontal region its dentations are least developed, towards the lower part becoming a sutura harmonia.

The persistence of the frontal portion of the sagittal suture is of very frequent occurrence, but its persistence through the membranous portion of the squama occipitalis is exceedingly rare, when present being almost, if not quite always, accompanied by a bisected interparietal.

The coronal suture is well marked and bounded behind by Wormian bones from one temporal fossa to the other.

The squamoparietal suture is completely obliterated by the confusion of Wormian bones in its vicinity, and the sphenoparietal, squamosphenoidal and mastoparietal sutures are only defined by the limitation of development of these supernumerary bones at the borders of the great wing of the sphenoid and mastoid portion of the temporal, as these are the lines of separation between the membranous and the chondrocranium.

The lambdoid suture is also obliterated, as it is impossible to trace it with any degree of precision through the mosaic of bones occupying this region.

As before mentioned, a well marked suture extends in a curved direction from one mastoid region to the other, crossing the center of the occipital just above the inion, marking out the lower limit of development of Wormian bones, or the separation in this region of the membranous and chondro- or primordial cranium.

The adventitious suture extending from the metopic to the coronal, and separating the large Wormian bone from the right half of the frontal, is long enough to merit special mention. It is reciprocally bevelled and feebly denticulated.

The rest of the cranial sutures are distinct, though a number of Wormian bones are intercalated in those surrounding the nasal notch of the frontal.

Fontanelles. As the whole squamæ temporales and adjacent portions of the parietals consist of Wormian bones, it is impossible to separately distinguish pterion and asterion ossicles.

A similar profusion of these bones in the posterior region of the skull makes it equally impossible to distinguish an *os Wormien lamdatique* in the posterior fontanelle. This complication does not exist at the bregma, where no bregmatic bone is present.

In each orbit there is an *os Wormien orbitaire* occupying the angle of junction of the frontal, os planum of the ethmoid and lesser wing of the sphenoid.

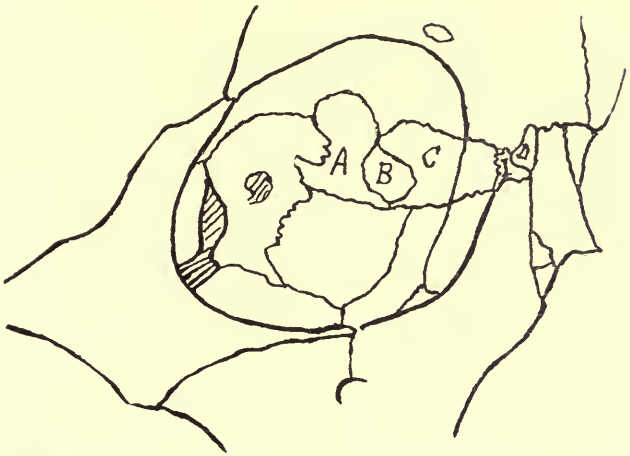

FIG. 21.—Right orbit. A, B, C, I, D, Wormian bones; A, occupying the orbital fontanelle.

The one in the right orbit measures 1 cm. wide by 2 cm. long, the long axis being obliquely vertical. (Fig. 21.) The one in the left orbit measures 7 mm. by 12 mm. and has the same relative direction as the right. (Fig. 22, page 42.)

This bone was not observed a single time in the nearly 500 skulls examined by Chambellan.

In the accompanying figures are shown other accessory bones in the orbits, four being visible in the right, and three in the left in the suture surrounding the nasal notch.

In the so-called abnormal fontanelles at the site of the nasofrontal suture, the fontanelle glabellaire, and at the obelion, the fontanelle

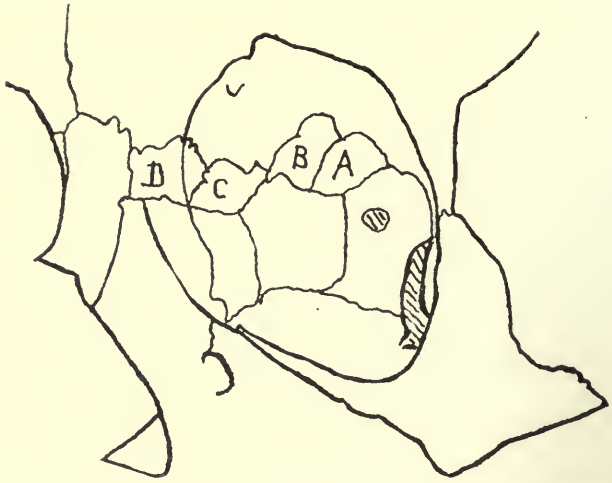

FIG. 22.—Left Orbit. A, B, C, D, Wormian bones; A, occupying the orbital fontanelle.

obelique, no example can be said to be present; in the first instance being definitely absent, and in the second, although the number of adventitious bones apparently leaves some room for doubt, none crosses the sagittal suture, demonstrating here also the absence of a special bone, or true *os Wormien obelique.*

Although so much of the cranium is composed of Wormian bones, yet the cranial anlage are well preserved, the principal sutures and bony areas being present and in their proper relations, showing that whatever general influences affected the skeleton, they were, in the skull at any rate, limited to osteogenesis, and not of earlier origin or farther reaching in their effects disturbing the fundamental elements and interfering with the type of development as is observed in the perverted chondrogenesis of chondrodystrophia foetalis, and frequently seen in monsters.

The same may be said of the rest of the skull; all the bones are present with their usual relations though the imperfect development of some produces considerable deformity, most marked in the recession of the face.

No similar condition in an adult skull has been recorded, and but two of a like nature have been observed in infants. These are the cases of Jung and Vrolik. Quoting from Hrdlicka, "Jung published in 1827 an observation on the skull of a new born male child, which showed, besides an extreme number of Wormian bones, irregular divisions in both parietals. The right bone was separated into five, the left into three por-

tions," and in referring to the same instance, Zeller remarks, "Jung says the disintegration of the whole cranium into intercalary bones is very rare."

In regard to the second case, Vrolik says, "The skeleton is from a new born infant of syphilitic parents.

"It died the third day; the following year the mother bore a healthy child. The whole osseous system was vitiated. This was most noted in the cranium, where no bone could be said to be intergrate. The frontal bone, the parietal bones, for the most part, and also the occipital bone, consisted of very many nuclei with irregular bones, which were joined by serrate margins, and gave to the cranium the appearance of being composed of very many little Wormian bones put together.

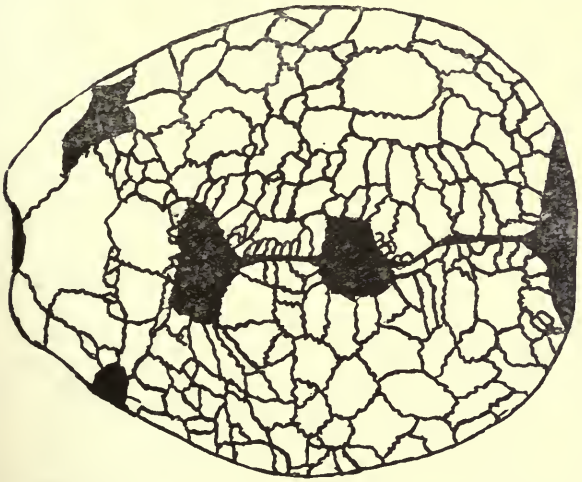

FIG. 23.—Osteogenesis imperfecta cranii. (After Vrolik.)

"Without doubt the cranium was expanded by hydrocephalous with a short and narrow face. The rest of the skeleton showed an imperfect state of the osseous system, with many fractures occupying all the ribs and long bones, some recent, some cured by callus. No doubt this was from imperfect osteogenesis, both as to form and texture of the bones."

The accompanying figure shows this infantile skull with its rich mosaic of supernumerary ossific nuclei to be an almost perfect minature of the one presented with this article. (Fig. 23.)

GENERAL SUMMARY.

CHAMBELLAN'S CONCLUSIONS.

Chambellan at the close of his exhaustive work presents the following conclusions:

The real name of Olaus Wormius is Olaüs Worm.

We may establish two categories of Wormian bones.

(1) The os Wormien suturaux.

(2) The os Wormien fontanellaires.

The os epactal and os interparietal should still be considered as different bones.

There are more Wormian bones in the lambdoid suture than in the others; they are also here the most voluminous. Following in order of frequency are the coronal, sagittal, squamous, masto-occipital and masto-parietal.

There are occasionally met in the sagittal suture certain Wormian bones of quite considerable size, and occupying always a place in the vicinity of the bregma, the obelion, or the lambda. In consequence they should be given the names os parabregmatique, paraobelique and paralamdatique, or better, sagittal-lambdoidien.

The skulls with obliterated sutures contain fewer Wormian bones than those in which the sutures are open or present.

There are more Wormian bones on the right side than on the left.

The Wormian bones are developed in two ways; the first, the usual manner, by the development of separate ossific nuclei, the second, by the absorption of pedicles of denticules leaving the minute extremities free.

In general they are more numerous in the larger crania.

This appears constant in all the groups examined, Auvergnats, Parisians, Neo-Caledonians, Negroes, Incas, microcephales, hemi-microcephales, apes and hydrocephales.

They are more numerous in brachycephales than in dolichocephales. This is notable, as the former have a greater average capacity than the latter.

In the Parisians, Auvergnats, Neo-Caledonians, Negroes, and Incas they are more abundant on the right side than on the left.

HYRTL'S RULES.

Hyrtl gives the following rules:

(1) They are found only in the cranium, and more in the true than in the false sutures. In the face but two examples have been personally observed, one in the crucial suture of the palate, the other in the internasal suture.

(2) They are more frequent in large skulls than in small.

(3) Their size varies from a flax seed to that of a dollar, which was observed in the anterior fontanelle.

(4) Paired Wormian bones on the cranial vault are more frequently symmetrical than not, but in the temporal fossa are as often asymmetrical as otherwise.

(5) They consist usually of two layers with diploe, their inner surface as a rule being smaller than the outer.

(6) Rarely they are found on the inner surface and not on the outer, more frequently do they appear only on the outer surface when they are always small. A rare form is the os insulare observed in the parietal near the margo squamosa.

AUTHOR'S CONCLUSIONS.

Wormian bones are properly named after Olaüs Worm, and his claim to priority of description is established by his letter to Thomas Bartholin.

To the two categories of Chambellan should be added the os insules of Manouvrier and Hyrtl.

The os interparietal should be limited to those single, or rarely several, elements representing the complete anlage of the membranous squama occipitalis.

The os Inca of Rivero and Tschudi is identical with the true interparietal; but the os epactal and os Inca as commonly defined have no definite morphological limits, and therefore no absolutely distinctive characteristics.

All observers agree to the preponderance of Wormian bones in the lambdoid suture. Their almost complete limitation to the sutures bordering the parietal bones is also noteworthy.

They develop either from original centres themselves or by segregation from pre-existing centres.

They vary in size from a millimetre in diameter to the one measuring 5 cm. by 9 cm. in the accompanying skull, probably the largest true Wormian bone ever recorded.

They are frequent in the crania of infants, and at times are doubtless synchronous in origin with the normal ossific centres.

The obliteration of the sutures by age or other causes diminishes their number by effacing the characteristic feature that distinguishes them from the adjacent bones.

True Wormian bones have no morphological value.

Their increased frequency in crania of large capacity is an apparently well established fact, the same rule applying whether enlarged from physiological or pathological causes.

Brachycephalic skulls have the greatest total sutural lengths. With Chambellan's observations that the brachycephalic skulls have the

greatest average capacity and the largest number of Wormian bones, this establishes a direct ratio between the number of Wormian bones, and the total sutural length.

In the 50 skulls examined by the writer the total dextral considerably exceeded the total sinistral sutural length. As Chambellan observed a dextral preponderance of Wormian bones in the skulls he examined, their excess on the right side further evidences the relation between the sutural length and the frequency of these bones.

Incidental. There is a definite increase in length of the coronal suture in brachycephalic skulls, and a slightly diminished length of the lambdoid and sagittal sutures. The lateral or squamous length shows a progressive increase from dolichocephales to brachycephales.

The great majority of Wormian bones are physiological in origin and compensatory in nature, and only when presenting distinctly unusual or abnormal features should a pathological origin be considered.

There are but three recorded cases in which Wormian bones are reputed to have exerted a pathological influence, causing still-birth of the fetus in each of the reported instances.

The case reported in this article is unique.

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Fig. 14.—Front View.

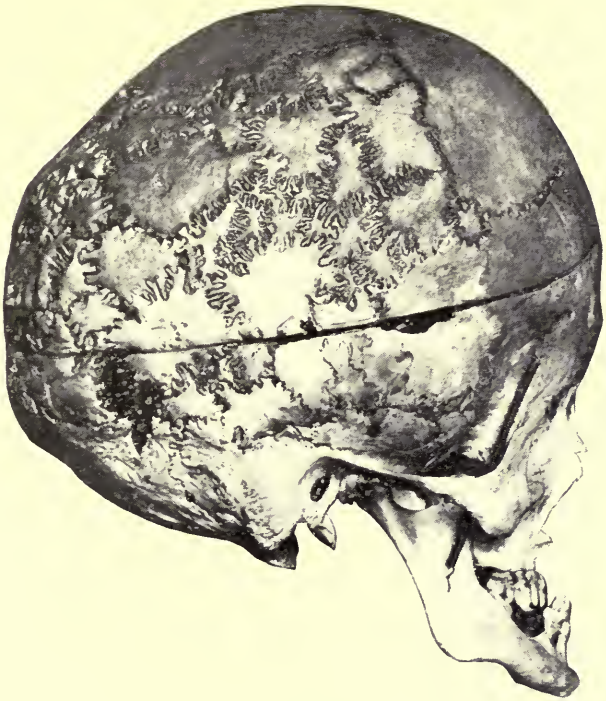

Fig. 15.—Lateral View.

Fig. 16.—Lateral View.

Fig. 17.—Posterior View.

Fig. 18.—View of Vertex.

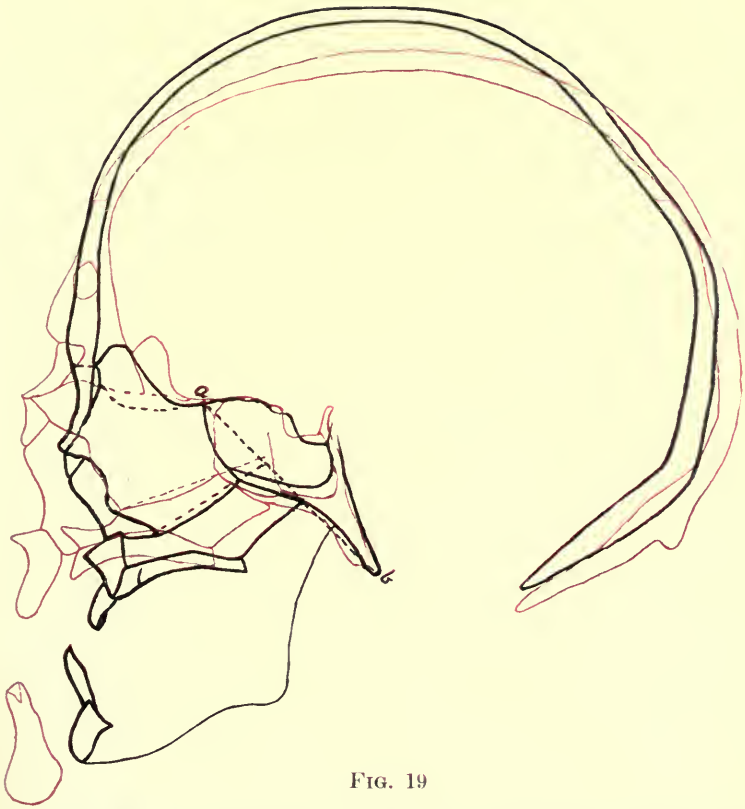

Fig. 19

Superimposed Outlines of Two Skulls with the Line *ab* Common to Both; the Present Skull Being Represented in Black, the Normal Skull in Red.

Fig. 20

Comparison of Facial Profiles, the Heavy Black Line Representing that of the Present Skull, the Heavy Red Line that of a Normal Skull.

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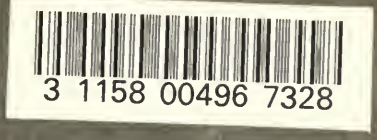

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